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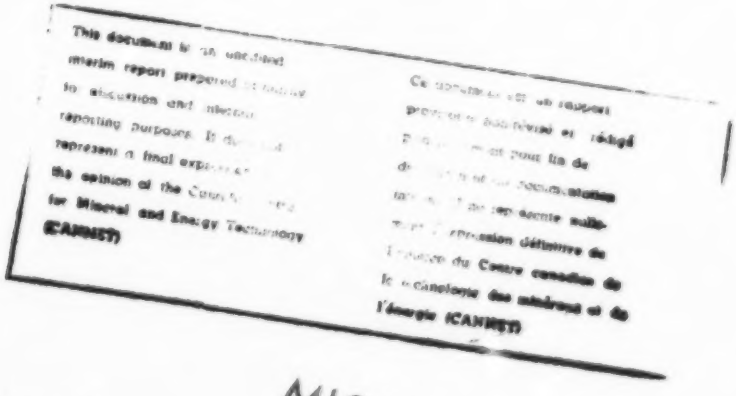
AN OVERVIEW OF MICRO-PROCESSOR BASED SYSTEMS FOR MONITORING EQUIPMENT PERFORMANCE

H.G. Naidu

February, 1987



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ABSTRACT

Numerous micro-processor based devices are now available to measure, analyze and report on equipment health and performance parameters. Industry experience to-date indicates acceptance of such devices. Major benefits accrue from the collection of accurate real-time data including clearer analysis of equipment performance, better definition of maintenance requirements and improved planning and scheduling ability.

This preliminary report provides an overview of available instrumentation. It is released now in order to bring this attractive technology to immediate notice of surface mining operations. Work on this project is continuing and a more comprehensive report will be issued later in the year.

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APERÇU DES SYSTÈMES COMMANDÉS PAR MICROPROCESSEURS SERVANT À SURVEILLER LE RENDEMENT DU MATÉRIEL

par

H. G. Naidu

RÉSUMÉ

Il existe actuellement de nombreux appareils commandés par microprocesseurs qui permettent de mesurer, d'analyser et d'indiquer l'état et le rendement du matériel. Ces appareils semblent jusqu'à maintenant bien acceptés dans l'industrie. La collecte de données exactes en temps réel offre de grands avantages, entre autres, une analyse plus précise du rendement du matériel, une meilleure définition des besoins d'entretien ainsi qu'une amélioration de la capacité de planification et d'ordonnancement.

Ce rapport préliminaire donne un aperçu des appareils disponibles sur le marché. Il est rendu public dès maintenant afin que le secteur de l'exploitation minière de surface connaisse le plus tôt possible cette merveilleuse technologie. Les recherches se poursuivent, et un rapport plus détaillé sera publié plus tard cette année.

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CONTENTS

	Page
ABSTRACT	i
RESUME	iii
CONTENTS	v
INTRODUCTION	1
MICRO-PROCESSOR TECHNOLOGY	1
AVAILABLE SYSTEMS	3
DRAGLINES	3
1) Digmate Plus/Boom Sentry Plus	3
2) DIGS Model 2010	5
3) Programmable Controllers (PC)	5
4) Model 173 Dragline Monitor	7
5) BEPAL II	7
SHOVEL	13
1) DIGS Model 5145	13
2) Model 173 Shovel Monitor	13
3) BEPAL II	13
BLASTHOLE DRILL	20
1) Model 245 Monitor	20
2) Holepro	20
3) GLI's Drilling Efficiency Indicator (DEI)	20
FRONT END LOADERS	22
1) DIGS Model 5155	22
BACKHOES	22
1) DIGS Model 3232	22
OFF-HIGHWAY TRUCKS	25
1) GLI's Vehicle Management System (VMS)	25
2) On Board Truck Weighing Systems	25
3) OBDAS System	27
4) TIACS System	29
DISCUSSION	32
REFERENCES	33

TABLES

Table I	Monitoring Devices for Draglines	9
Table II	Monitoring Devices for Shovels	19
Table III	Monitoring Devices for Drills	24
Table IV	Monitoring Devices for Trucks	31

FIGURES

Figure 1	Sensors on dragline continuously gather data, which are fed to onboard computer that records output and guides operator	2
Figure 2	DIGMATE/BOOMSENTRY system components (4)	4
Figure 3	Dragline operation report	6
Figure 4	Block diagram of entire programmable controller network (2)	8
Figure 5	The base station consists of CRT programmer (left), printer, rack holding PC interface modules and modem (below rack) (2)	8
Figure 6	Dragline - BEPAL II, Daily Management Report (5) ..	10
Figure 7	Dragline - BEPAL II, Productivity/Utilization Report (5)	11
Figure 8	Dragline - BEPAL II, Availability Summary Report (5)	12
Figure 9	BEPAL - II (5)	15
Figure 10	Shovel - BEPAL II, Productivity/Utilization Report (5)	16
Figure 11	Shovel - BEPAL II, Daily Management Report (5)	17
Figure 12	Shovel - BEPAL II, Availability Summary Report (5)	18
Figure 13	Holepro drill monitor (5)	21
Figure 14	GLI's DEI System (7)	23
Figure 15	Vehicle Management System (7)	26
Figure 16	OBDAS System (3)	28
Figure 17	Typical OBDAS Output (3)	30

INTRODUCTION

The Canadian coal mining industry is facing a stiff challenge due to downward pressure on product prices as well as a reduction in coal sales. Though the industry enjoys high productivity achieved through heavy mechanization these factors demand further gains in productivity and cost reduction. One area that could contribute to enhanced equipment productivity is the application of computerized performance and health monitoring and controlling devices. Some coal mining companies in U.S.A with established computer expertise have developed their own monitoring systems. Commercially companies like General Electric, Mining Electronic Equipment, Interactive Sciences, Bucyrus Erie and others have developed and introduced such devices in surface mines world-wide. There is a growing interest in Canada in this technology and already several mines have installed selected instrumentation. This preliminary report presents the findings of a survey carried out by the author on the current usage and performance of different devices.

MIRCO-PROCESSOR TECHNOLOGY

Micro-processor technology although widely used in other industries has found acceptance in mining only during the last five years. Based on this technology various types of monitoring systems have become available for measuring equipment performance. Basically, the systems utilized for draglines, shovels, loaders or backhoes consist of sensors, input/output modules, processor module and a CRT screen. As an illustration Fig.1 shows a schematic of a dragline with six sensors installed for gathering data on power consumption, hoist rope force(amps), drag rope force(amps), hoist drum position, drag drum position and swing angle. These sensors send signals to the input module which converts them to voltage levels acceptable to the processor. The output module receives signals from the processor and transmits operating information to a colour CRT monitor located inside the operator's cabin. This information is provided in easily understood vords or graphic displays, indicating exactly how well the machine is functioning and producing. The operator can also identify dragline activity or downtime by simply entering coded inputs on the CRT keyboard. Automatically recorded operating data is provided, eliminating the need for time sheets and other

manual record keeping methods. Additionally, there are audio and visual alerts when unsafe conditions such as tightlining and motor stall occur, thereby preventing accidents. Such a system was recently described in an article published in Coal Age (1). The user mine claims greater machine utilization and lower operating costs.

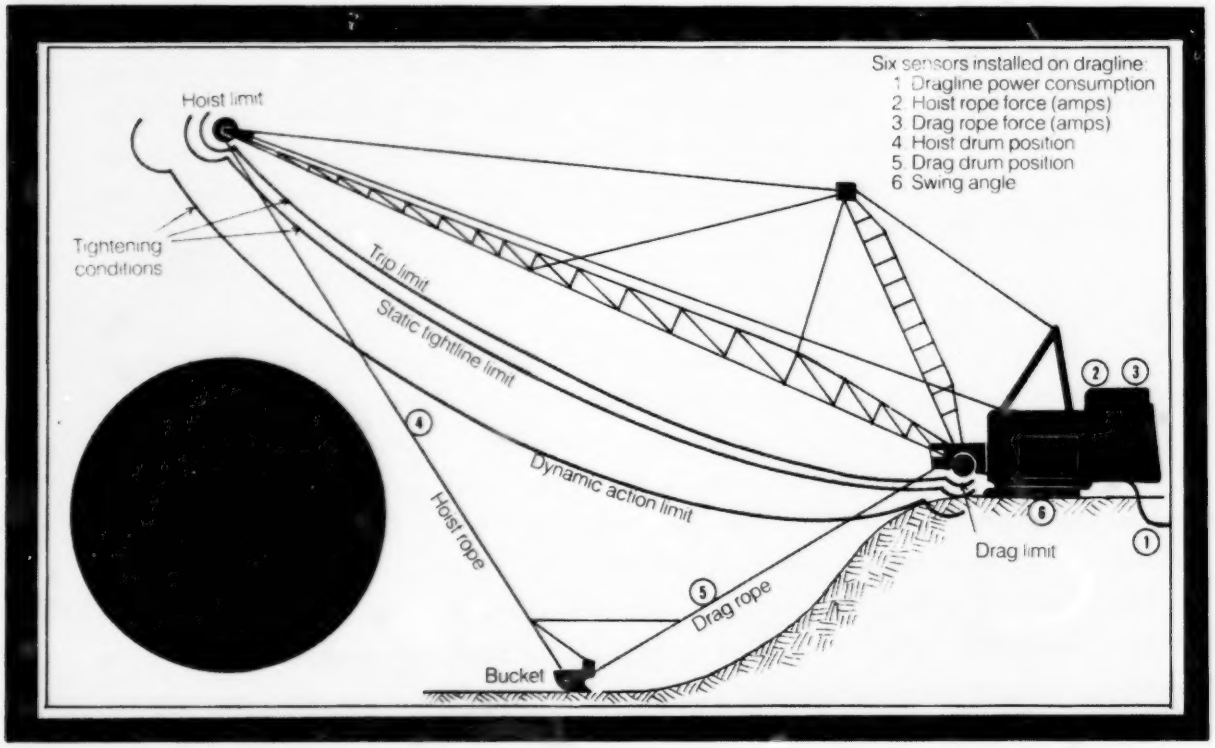


FIG. 1 Sensors on dragline continuously gather data, which are fed to onboard computer that records output and guides operator. (1)

Similar systems are available for on-vehicle weighing instrumentation; drilling efficiency indicators mounted on blast hole machines providing rate of penetration, depth drilled, distance from bottom, accumulated depth etc.; on-board health monitoring and equipment operating environment analysis (shock,vibration,temperature extremes etc.);anti-collision technology etc.

AVAILABLE SYSTEMS:

The previously described dragline system is one example of the variety of equipment monitoring devices that are commercially available. In the following sections the range of devices available for different classes of equipment are described. To facilitate comparison the described devices are also summarized in Tables I to IV.

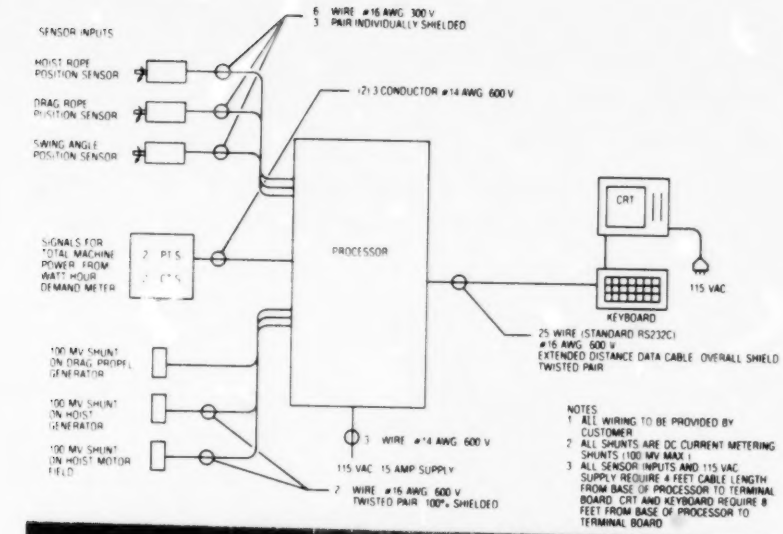
DRAGLINES:

1) Digmate Plus/Boom Sentry Plus:

This system is designed and manufactured by General Electric Drive Systems Department, Erie, PA., U.S.A. Several of these systems have been installed on draglines throughout the world including U.S.A., South Africa, U.K. and Canada.

The Digmate Plus is an on-board excavator monitor and production reporting system. It continuously monitors seven sensor inputs (Fig.2); the inputs monitored are:

- Total dragline power (kw)
- Hoist rope force (armature amps)
- Drag rope force (armature amps)
- Hoist motor field strength (field amps)
- Hoist rope position (hoist drum position)
- Drag rope position (drag drum position)
- Swing angle (swing position)


SENSOR INPUTS
HOIST ROPE POSITION SENSOR
DRAG ROPE POSITION SENSOR
SWING ANGLE POSITION SENSOR
SIGNALS FOR TOTAL MACHINE POWER FROM WATT HOUR DEMAND METER
100 MV SHUNT ON DRAG PROPEL GENERATOR
100 MV SHUNT ON HOIST GENERATOR
100 MV SHUNT ON HOIST MOTOR FIELD
6 WIRE #16 AWG 300 V 3 PAIR INDIVIDUALLY SHIELDED
(2) 3 CONDUCTOR #14 AWG 600 V
PROCESSOR
CRT
115 VAC
KEYBOARD
25 WIRE (STANDARD RS232C) #16 AWG 600 V EXTENDED DISTANCE DATA CABLE OVERALL SHIELD TWISTED PAIR
3 WIRE #14 AWG 600 V
115 VAC 15 AMP SUPPLY
2 WIRE #16 AWG 600 V TWISTED PAIR 100% SHIELDED
NOTES
1 ALL WIRING TO BE PROVIDED BY CUSTOMER
2 ALL SHUNTS ARE DC CURRENT METERING SHUNTS (100 MV MAX.)
3 ALL SENSOR INPUTS AND 115 VAC SUPPLY REQUIRE 4 FEET CABLE LENGTH FROM BASE OF PROCESSOR TO TERMINAL BOARD. CRT AND KEYBOARD REQUIRE 8 FEET FROM BASE OF PROCESSOR TO TERMINAL BOARD

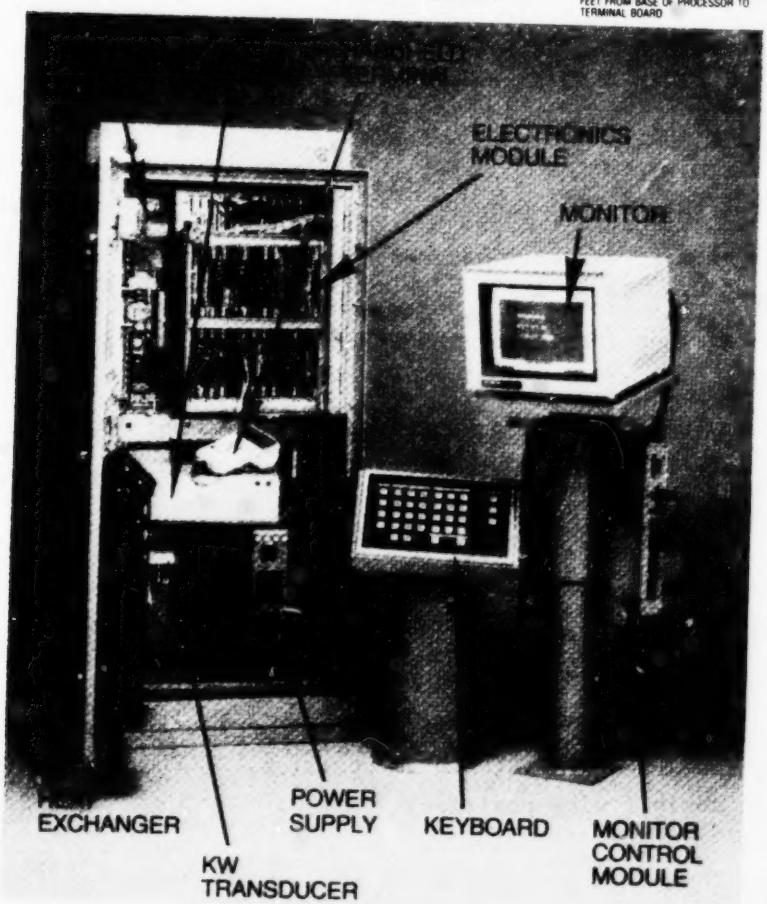


FIG. 2 DIGMATE/BOOMSENTRY system components (4).

From these inputs a total of 32 dragline parameters can be calculated, displayed on the operators monitor and stored in the computer memory. It provides immediate evaluation of productivity, as well as standard production reports by shift, detailing cycle times, production rates, loading data, swing angles, power consumption, rope loading and a comprehensive listing of downtime and delays (Fig.3). It also includes all the necessary IBM compatible software needed to generate a detailed production report, which can be readily reformatted and stored to generate weekly, monthly or annual reports.

The Boom Sentry Plus is an anti-tightline control system designed to protect dragline booms from structural damage caused by either excessive mechanical loading or by the bucket swinging etc. The protection functions performed are hoist and drag overtravel limits, hoist in and drag in limits, and prevention of operation which could lead to a static or dynamic tightline condition.

2) DIGS Model 2010:

Designed and manufactured by Mining Electronic Equipment (MEE) this model is reportedly one of the first computerized dragline information gathering system with full on-board display and report printing capability. The main features including anti-tightline control are similar to General Electric's Digmate Plus/Boom Sentry Plus system. This system has been installed on several draglines in the U.S.A. Recently, due to heavy competition in this area the company has decided to suspend manufacturing of this system, only servicing and maintenance of existing systems is provided.

In the MEE system data from the on-board system can be transmitted via radio waves . Also one or more on-board systems can be coupled via Data Link to provide a Mine Wide Data Management System.

3) Programmable Controllers (PC):

An example of the application of programmable controllers(PC) is provided by Trapper Mining Inc., Craig, Colorado. In the PC design three objectives were aimed at, namely: lubrication pumping, anti-tightline control and production data collection. Details on this application are given in reference (2).

1. PRODUCTION SUMMARY: (DENSITY = 1.50 T/CM, BUCKET WT = 37.T)

A. PRODUCTIVE DIGGING

CODE	DESCRIPTION	TIME ANALYSIS HOURS	%T	RETURN MAT. TONNES	CM	DIGGING ANALYSIS TONNES	CM	CM/HR
00	STRIPPING	6.64	55.33	46.	30.	24789.	16533.	2490.
02	KEY CUT	1.04	8.66	0.	0.	3315.	2210.	2125.
08	TRAINING	0.75	6.25	0.	0.	2041.	1361.	1815.
14	OTHER DIGGING	0.14	1.16	0.	0.	486.	324.	23
SUB TOTAL		8.57	71.42	46.	30.	30631.	20368.	2377.

B. NON-PRODUCTIVE DIGGING

15	REHANDLE	0.66	5.50	0.	0.	2460.	1636.	2478.
16	ROADS	0.33	2.75	0.	0.	1230.	818.	2479.
SUB TOTAL		0.99	8.25	0.	0.	3690.	2454.	2479.
TOTAL		9.58	79.82	46.	30.	34322.	22822.	2362.

2. WALKING SUMMARY:

		HOURS	%T	NUMBER OF STEPS
18	NORMAL WALK	0.17	1.42	12
19	OTHER WALK	0.03	0.25	2
TOTAL		0.20	1.67	14

3. OPERATOR DELAY:

		HOURS	%T
22	SHIFT CHANGE	0.07	0.59
23	MEALS	0.52	4.34
26	BLASTING	0.20	1.66
TOTAL		0.79	6.59

4. OPERATING MAINT:

40	DUMP RIGGING	0.15	1.25
42	TEETH	0.13	1.08
TOTAL		0.28	2.33

5. ELECTRICAL MAINT:

		HOURS	%T
55	HOIST GENERATOR	0.54	4.51
TOTAL		0.54	4.51

6. MECHANICAL MAINT:

TOTAL		0.00	0.00

7. SYSTEM:

100	UNIDENTIFIED	0.61	5.08
TOTAL		0.61	5.08

8. DIGGING ANALYSIS:

SWING ANGLE	SINGLE PASSES NO.	%T	MULTIPLE PASSES NO.	%T	TOTAL CYCLES NO.	%T	RETURN MAT. CYCLES NO.	TONNES
0- 20	4	0.7	1	0.2	5	0.9	0	0.
20- 40	17	3.0	14	2.5	31	5.6	0	0.
40- 60	32	5.8	1	0.2	33	5.9	0	0.
60- 80	209	37.4	13	2.3	222	39.8	3	25.
80-100	158	28.3	22	3.9	180	32.2	2	18.
100-120	54	9.8	4	0.7	58	10.4	0	0.
120-140	24	4.3	1	0.2	25	4.5	0	0.
140-160	4	0.7	0	0.0	4	0.7	0	0.
160-180	0	0.0	0	0.0	0	0.0	0	0.
180-270	0	0.0	0	0.0	0	0.0	0	0.
270-360	0	0.0	0	0.0	0	0.0	0	0.
TOTAL DIGS	502	90.0	56	10.0	558	100.0	5	46.
TOTAL HOURS	8.24		1.44		9.58			

	SINGLE PASS	MULTIPLE PASS	TOTAL
AVG CYCLE TIME, SEC	59.1	86.1	61.8
AVG BUCKET LOAD TIME, SEC	17.8	52.1	19.6
AVG BUCKET LOADING FORCE, %STALL	63.4	51.6	62.5
AVG VERTICAL HOIST DISTANCE, M	52.3	41.7	51.9
AVG DRAG DISTANCE, M	30.0	58.0	33.0
MAX BUCKET LOADING DEPTH,M	53.0	33.0	53.0

9. ELECTRICAL ANALYSIS:

SUMMATION FOR ENTIRE SHIFT

TOTAL KWH INTO D/L =	13553.
REGEN KWH RECOVERY =	-1598.
NET KWH USED =	11955.
MAX 15 MIN DEMAND, KW =	1935.
AVG 15 MIN DEMAND, KW =	1430.

SUMMATION FOR DIGGING PERIOD ONLY

RMS DRAG AMPS =	1815.
RMS HOIST AMPS =	2040.
AVG KWH USED/DIG =	24.
MAX PEAK KW INTO D/L =	5475.
AVG PEAK KW INTO D/L =	3973.
MAX PEAK REGEN KW OUT =	-3929.
AVG PEAK REGEN KW OUT =	-2408.

10. MECHANICAL ANALYSIS:

DRAG ROPE MOVED, M =	60093.	HOIST ROPE MOVED, M =	56285.
DRAG ROPE WEAR INDEX =	201565.	HOIST ROPE WEAR INDEX =	349336.

11. OPERATOR SUMMARY:

OPR NO.	NO. DIGS	CYCLE TIME	CM MOVED	WALKING HOURS	DELAYING HOURS	ALARM/STOP HOIST STALL	DRAG STALL	HOIST-IN LIMIT	DRAG-IN LIMIT	TIME LINE
2	527	60.3	21822	0.20	2.02	0	2	1/0	0/1	0/0
99	31	87.1	1240	0.00	0.20	0	0	0/0	0/0	0/0
0	0	0.0	0	0.00	0.00	0	0	0/0	0/0	1/0
0	0	0.0	0	0.00	0.00	0	0	0/0	0/0	0/0

FIG. 3 Dragline operation report. (4)

There are three operating draglines at this mine. All have been provided with this system. Fig.4 is a block diagram of entire programmable controller network. There is a radio link from the base station to the draglines. A cable connects the three PC's inside each dragline to provide information on antitightline, lube and data gathering. Fig.5 shows the base station which consists of a CRT programmer(left), printer, rack holding PC interface modules and a Modem. To program a PC processor, a diagram is constructed on the CRT screen in the base station. When ready, the load button is pressed so that the program is transmitted to the processor directing the processor when to activate machinery or perform other functions. A PC system consists of three modules: input, output and a processor module.

4) Model 173 Dragline Monitor:

This is designed and manufactured by Interactive Sciences Inc. of Florida, U.S.A. The microprocessor based system provides the operator with a display of the number of dumps, swings, swing angle, propel time, cycle time and many other machine functions. The system provides a printed log and shift report and records all activity on magnetic tape for further analysis by the Tape Processing System (Model 223). At the present time this system is installed on over fifteen draglines in the U.S.A.

5) BEPAL II:

Bepal II monitoring system designed by Bucyrus Erie(BE) is a multipurpose unit and can be used on a variety of equipment including draglines. The general features are very much similar to other monitoring devices described earlier. Currently the device is being modified to include anti-tightline control. More details on this unit are given in the section for shovels. The standard outputs resulting from this system are shown in Figures 6, 7 and 8.

A summary of these various dragline performance monitoring devices is given in Table I.

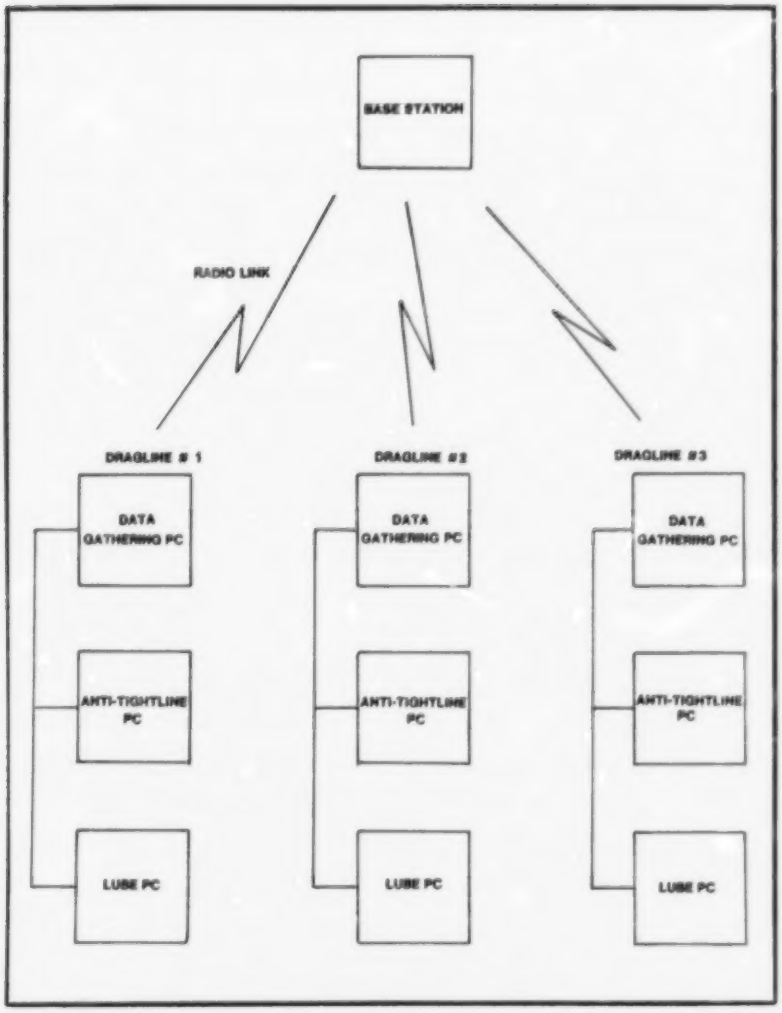


FIG. 4 Block diagram of entire programmable controller network. (2)

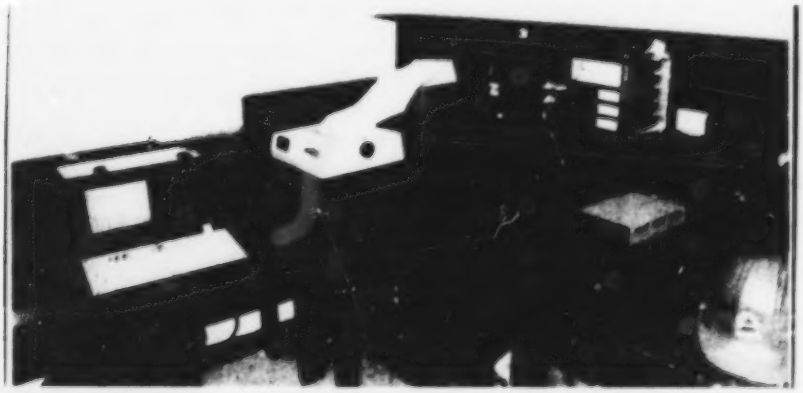


FIG. 5 The base station consists of CRT programmer (left), printer, rack holding PC interface modules and modem (below rack). (2)

TABLE I

MONITORING DEVICES FOR DRAGLINES

Description	Nature of the Manufacturers	Locations Currently Operating	Features	Cost Estimate	Remarks
Digmate Plus/ Boom Sentry Plus	General Electric Drive Syetems Operations Salem, Virginia 24153, U.S.A.	Over 60 installations throughout the world including U.S.A., U.K. and South Africa	Data gathering Antitight Line Control	$100,000.00	Proven System
Dig Model 2010	Mining Electronic Equipment, Plaintview Pointe, Suite 100, 10509 Timberwood Circle, Louisville, Kentucky, 40223, U.S.A.	U.S.A.	Data gathering Antitight Line	$100,000.00	Suspended Production
Programmable Controllers	Trapper Mining Co. Craig, CO, U.S.A.	Trapper mine Craig, CO, U.S.A.	Data gathering Antitight Line Lube pumping	$ 50,000.00	Developed in-house
Model 173	Interactive Sciences, P.O. Box 1896, Sanford, Florida 32772, USA	On fifteen draglines in U.S.A.	Data gathering	Less than $100,000.00	Proven System
Bepal II	Bucyrus Erie P.O. Box 56 South Milwaukee, WI., 53172, U.S.A.	U.S.A. Manalta is planning to install at Poplar River Mine on Marion 8750	Data gathering	Less than $100,000.00	Design for antitight line is in progress.

DRAGLINE NO: DG1 DATE: 1/1/86 TIME: 07:00

	PARAMETERS	24 HOURS	SHIFT: 1	SHIFT: 2	SHIFT: 3	M-T-D TOTALS
1.	Total Yards Moved (Density)	XXXXXX	XXXXX	XXXXX	XXXXX	XXXXXXXX
2.	Total Tons Moved	XXXX	XXXX	XXXX	XXXX	XXXXXX
3.	Total Number of Dig Cycles	XXXX	XXX	XXX	XXX	XXXXX
4.	Total Number of Multiple Pass Cycles	XX	XX	XX	XX	XXX
5.	Avg. Number Dig Cycles/Hour	XX	XX	XX	XX	XX
6.	Avg. Yards/Cycle (Density)	XXX	XXX	XXX	XXX	XXX
7.	Avg. Tons/Cycle	XXX	XXX	XXX	XXX	XXX
8.	Avg. Fill Factor	XXX	XXX	XXX	XXX	XXX
9.	Avg. Yards/Hour (Density)	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
10.	Avg. Tons/Hour	XXX	XXX	XXX	XXX	XXX
11.	Avg. Dump Height	XXX	XXX	XXX	XXX	XXX
12.	Avg. Digging Depth	XXX	XXX	XXX	XXX	XXX
13.	Avg. Swing Angle	XX	XX	XX	XX	XX
14.	Avg. Total Cycle Time	XX	XX	XX	XX	XX
15.	Availability (%)	XXX	XXX	XXX	XXX	XXX
16.	Available Digging Hours	XX	XX	XX	XX	XXX
17.	% Available Hours Oper.	XXX	XXX	XXX	XXX	XXX
18.	Total Digging Time	XX	XX	XX	XX	XXX
19.	Total Downtime	XX	XX	XX	XX	XXX
	— Total Mechanical Delays	XX	XX	XX	XX	XXX
	— Total Electrical Delays	XX	XX	XX	XX	XXX
	— Total Operational Delays	XX	XX	XX	XX	XXX
20.	Total Propel Time	XX	XX	XX	XX	XXXX
21.	Total Propel Distance	XXXX	XXX	XXX	XX	XXXX
22.	Total KWH	XXXXX	XXXX	XXXX	XXX	XXXXXX
23.	Avg. 15 Min. Demand	XXXX	XXXX	XXXX	XXXX	XXXX
24.	KWH (Motions): Drag	XXXX	XXXX	XXXX	XXXX	XXXX
	: Hoist	XXXX	XXXX	XXXX	XXXX	XXXX
	: Swing					

FIG. 6 Dragline - BEPAL II, Daily Management Report (5).

DRAGLINE NO: DG1 DATE: 1/1/86 Time: 07:00

PARAMETERS	SHIFT: 1	OP ID:	OP ID:	OP ID:	M-T-D TOTAL
1. Total Yards (Density)	XXXXX	XXXXX	XXXXX	XXXXX	XXXXXXX
2. Total Tons Moved	XXXX	XXXX	XXXX	XXXX	XXXX
3. Total Number of Dig Cycles	XXX	XXX	XXX	XXX	XXXXXX
4. Total Number Multiple Pass Cycles	XXX	XXX	XXX	XXX	XXX
5. Avg. Number Dig Cycles/Hour	XX	XX	XX	XX	XX
6. Avg. Yards/Cycle (Density)	XXX	XXX	XXX	XXX	XXX
7. Avg. Fill Factor (%)	XXX	XXX	XXX	XXX	XXX
8. Avg. Yards/Hour	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
9. Avg. Dump Height	XXX	XXX	XXX	XXX	XXX
10. Avg. Digging Depth	XXX	XXX	XXX	XXX	XXX
11. Avg. Swing Angle	XX	XX	XX	XX	XX
12. Avg. Total Cycle Time	XXX	XXX	XXX	XXX	XXX
-- Avg. Bucket Fill Time	XX	XX	XX	XX	XX
-- Avg. Swing to Spoil Time	XX	XX	XX	XX	XX
-- Avg. Dump Time	XX	XX	XX	XX	XX
-- Avg. Return Swing Time	XX	XX	XX	XX	XX
-- Avg. Set to Dig Time	XX	XX	XX	XX	XX

	MECHANICAL	ELECTRICAL	OPERATIONAL	TOTALS
Scheduled Delays	XX.X/%	XX.X/%	XX.X/%	XX.X/%
Unscheduled Delays	XX.X/%	XX.X/%	XX.X/%	XX.X/%
Grand Total	XX.X/%	XX.X/%	XX.X/%	XX.X/%

AVAILABLE DIGGING HOURS XX
% AVAILABLE HOURS OPERATED XXX

MECHANICAL AVAILABILITY (%) XXX
ELECTRICAL AVAILABILITY (%) XXX
OPERATIONAL AVAILABILITY (%) XXX

TOTAL AVAILABILITY (%) XXX
MACHINE UTILIZATION (%) XXX

TOTAL KWH: XXXX
AVG. 15 MIN. DEMAND: XX
KWH (MOTIONS): DRAG: XXX HOIST: XXX SWING: XXX

FIG. 7 Dragline - BEPAL II, Productivity/Utilization Report (5).

DRAGLINE NO: DATE: SHIFT: TIME:

TOTAL AVAILABILITY: % MACHINE UTILIZATION: %

SCHEDULED DELAYS				UNSCHEDULED DELAYS			
MECHANICAL:	TOTAL:	(HOURS)	(%)	MECHANICAL:	TOTAL:	(HOURS)	(%)
CODE -- DESCRIPTION		HOURS	%	CODE -- DESCRIPTION		HOURS	%
XX	XXXXXXXXXX	XX.X	XX	XX	XXXXXXXXXX	XX.X	X
XX	XXXXXXXXXX			XX	XXXXXXXXXX	XX.X	X
TOTAL MECHANICAL DELAYS:		(HOURS)	(%)				
ELECTRICAL:	TOTAL:	(HOURS)	(%)	ELECTRICAL:	TOTAL:	(HOURS)	(%)
CODE -- DESCRIPTION		HOURS	%	CODE -- DESCRIPTION		HOURS	%
XX	XXXXXXXXXX	XX.X	XX	XX	XXXXXXXXXX	XX.X	X
XX	XXXXXXXXXX	XX.X	XX	XX	XXXXXXXXXX	XX.X	X
TOTAL ELECTRICAL DELAYS:		(HOURS)	(%)				
OPERATIONAL:	TOTAL:	(HOURS)	(%)	OPERATIONAL	TOTAL:	(HOURS)	(%)
CODE -- DESCRIPTION		HOURS	%	CODE -- DESCRIPTION		HOURS	%
XX	XXXXXXXXXX	XX.X	XX	XX	XXXXXXXXXX	XX.X	X
XX	XXXXXXXXXX	XX.X	XX	XX	XXXXXXXXXX	XX.X	X
TOTAL OPERATIONAL DELAYS:		(HOURS)	(%)				
TOTAL SCHEDULED DELAYS:				TOTAL UNSCHEDULED DELAYS:			
HOURS: XX.X %				HOURS: XX.X %			

FIG. 8 Dragline - BEPAL II, Availability Summary Report (5).

SHOVEL:

1) DIGS Model 5145:

This is designed and manufactured by MEE of Kentucky, U.S.A and is in operation on several shovels in the U.S.A. It is a computer based system which monitors cycle time, dipper fill and safety conditions. Truck overloading can be prevented as the operator receives updated weight information as each dipper is filled and dumped. At the end of each shift a truck report summarizes the time of each loading, payload, truck and shovel identification. Availability of this data provides an excellent tool for quantitative analysis of the mining operations to isolate and identify operation obstacles.

2) Model 173 Shovel Monitor:

This system designed and manufactured by Interactive Sciences Inc., is installed on over twenty five shovels in the U.S.A. This system is also being tested at some coal mines in western Canada. It obtains, records and processes machine operating data and produces necessary reports similar to those described for draglines.

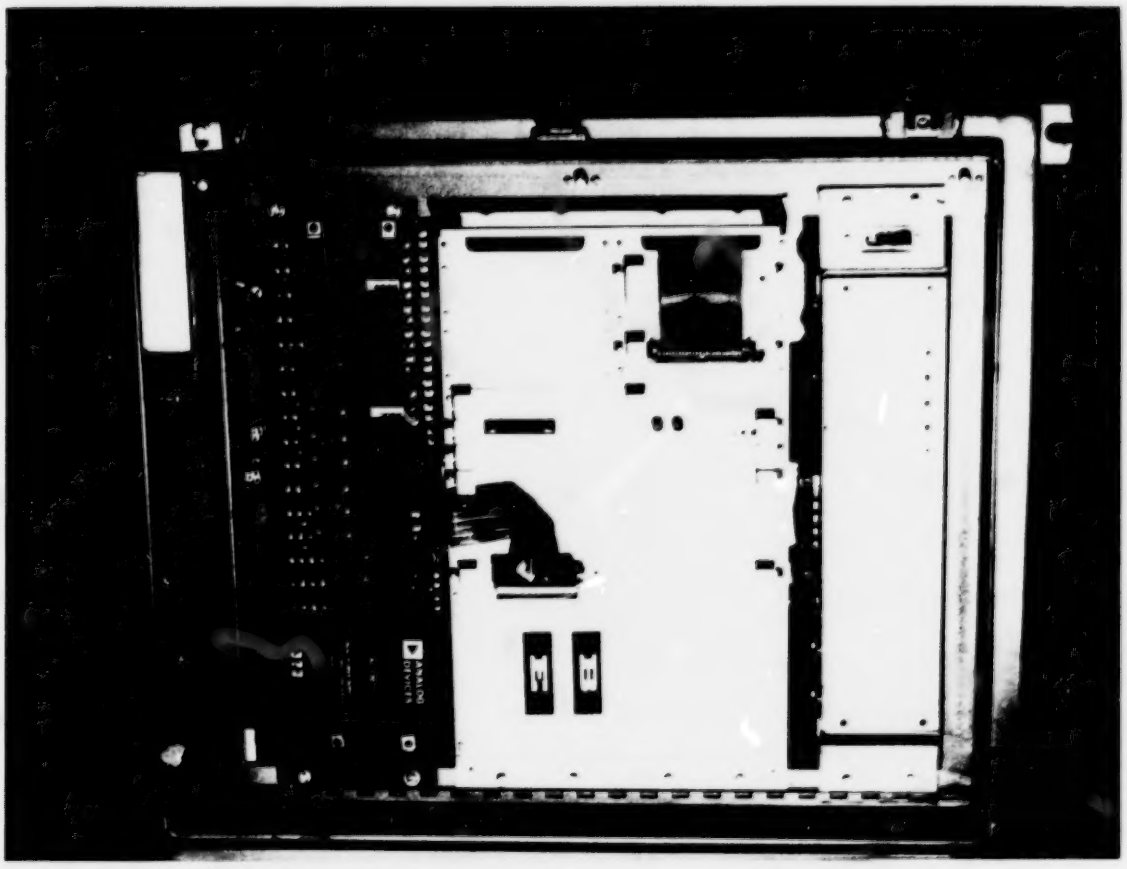
3) BEPAL II:

This system has been designed, manufactured and marketed by Bucyrus-Erie's Mining Systems Division for electric mining shovels, draglines and other loading machines (Fig.9). The features of BEPAL II include:

- Dynamic measurement of load/volume per cycle
- Accumulated load per truck and/or shift
- Cycle time analysis
- Availability/utilization control
- Overload/underload analysis
- Convenient keypad/display
- On-board printer
- Modem/radio for telemetering
- Flexible, expandable system

This system appears to be gaining importance in Canada as well as many other countries. Currently this unit is in operation on shovels at Cardinal River, Alta., Syncrude, Alta., Iron Ore Co., Nfld., Quebec Cartier

Mining Co., Que. and Highland Valley, B.C. The standard outputs are shown in figures 10, 11 and 12. The summary of different shovel monitoring devices is given in Table II.



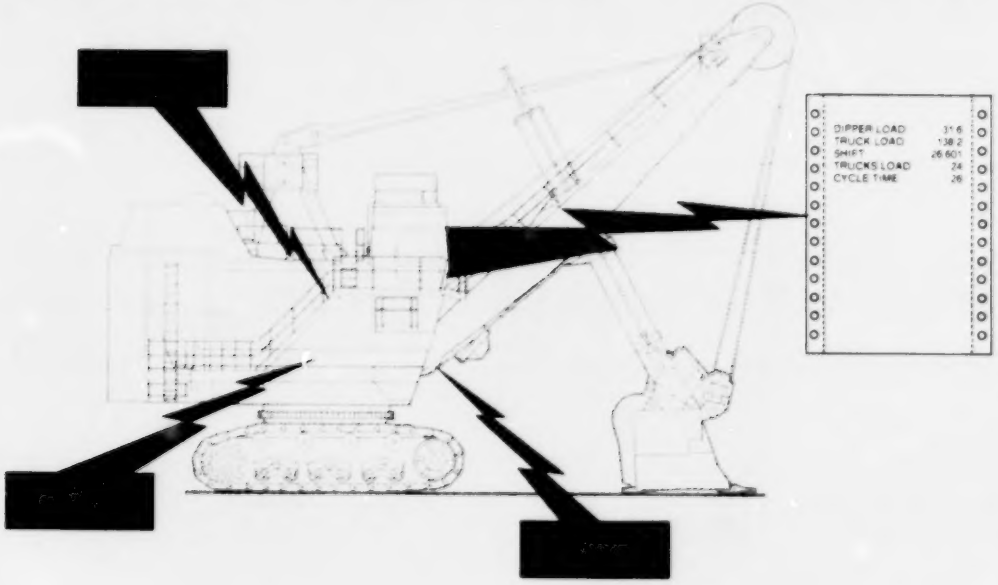


FIG. 9 BEPAL - II (5).

SHOVEL NO: 14 DATE: 1/1/86 SHIFT: 1 TIME: 15:01

PARAMETERS	SHIFT: 1	OP ID:	OP ID:	OP ID:
1. Total Tons Moved	XXXX	XXXX	XXXX	XXXX
2. Total Yards Moved (Density)	XXXX	XXXX	XXXX	XXXX
3. Total Trucks Loaded	XX	XX	XX	XX
4. Avg. Truck Load (Tons)	XXX	XXX	XXX	XXX
5. Avg. Shovel Load (Tons)	XX	XX	XX	XX
6. Avg. Overload (Tons)	XX	XX	XX	XX
7. Total Overloaded	XX	XX	XX	XX
8. Avg. Underloaded (Tons)	XX	XX	XX	XX
9. Total Underloaded	XX	XX	XX	XX
10. Avg. Fill Time (Seconds)	XXX	XXX	XXX	XXX
11. Avg. Shovel Cycle Time (Seconds)	XX	XX	XX	XX
-- Avg. Swing Angle	XX	XX	XX	XX
-- Avg. Bucket Fill Time	XX	XX	XX	XX
-- Avg. Swing to Truck Time	XX	XX	XX	XX
-- Avg. Dump Time	XX	XX	XX	XX
-- Avg. Return Swing Time	XX	XX	XX	XX

	MECHANICAL	ELECTRICAL	OPERATIONAL	TOTALS
Scheduled Delays	XX.X/%	XX.X/%	XX.X/%	XX.X/%
Unscheduled Delays	XX.X/%	XX.X/%	XX.X/%	XX.X/%
Grand Total	XX.X/%	XX.X/%	XX.X/%	XX.X/%

MECHANICAL AVAILABILITY (%) XXX
ELECTRICAL AVAILABILITY (%) XXX
OPERATIONAL AVAILABILITY (%) XXX

TOTAL AVAILABILITY (%) XXX
MACHINE UTILIZATION (%) XXX

FIG. 10 Shovel - BEPAL II, Productivity/Utilization Report (5).

SHOVEL NO: 14 DATE: 1/1/86 SHIFT: 1 TIME: 15:01

PARAMETERS	24 HOURS	SHIFT: 1	SHIFT: 2	SHIFT: 3
1. Total Tons Moved		XXXX		
2. Total Yards Moved (Density)		XXXX		
3. Total Trucks Loaded		XX		
4. Average Truck Load (Tons)		XXX		
5. Average Overload (Tons)		XX		
6. Total Trucks Overloaded		XX		
7. Average Underload (Tons)		XX		
8. Total Trucks Underloaded		XX		
9. Avg. Shovel Cycle Time (Sec.)		XX		
10. Avg. Truck Loading Time (Sec.)		XXX		
11. Availability (%)		XXX		
12. Total Downtime (Hours)		XX.X		
-- Total Mechanical Delays		XX.X		
-- Total Electrical Delays		XX.X		
-- Total Operational Delays		XX.X		
13. Available Digging Hours		XX.X		
14. % Available Hours Operated		XXX		
15. Total Digging Time		XX.X		

FIG. 11 Shovel - BEPAL II, Daily Management Report (5).

SHOVEL NO: DATE: SHIFT: TIME:

TOTAL AVAILABILITY: % MACHINE UTILIZATION: %

SCHEDULED DELAYS				UNSCHEDULED DELAYS			
MECHANICAL: CODE -- DESCRIPTION	TOTAL: HOURS	(HOURS) %	(%)	MECHANICAL: CODE -- DESCRIPTION	TOTAL: HOURS	(HOURS) %	(%)
XX XXXXXXXXXX	XX.X	XX		XX XXXXXXXXXXX	XX.X	X	
XX XXXXXXXXXX				XX XXXXXXXXXXX	XX.X	X	
TOTAL MECHANICAL DELAYS:		(HOURS)	(%)				
ELECTRICAL: CODE -- DESCRIPTION	TOTAL: HOURS	(HOURS) %	(%)	ELECTRICAL: CODE -- DESCRIPTION	TOTAL: HOURS	(HOURS) %	(%)
XX XXXXXXXXXX	XX.X	XX		XX XXXXXXXXXXX	XX.X	X	
XX XXXXXXXXXX	XX.X	XX		XX XXXXXXXXXXX	XX.X	X	
TOTAL ELECTRICAL DELAYS:		(HOURS)	(%)				
OPERATIONAL: CODE -- DESCRIPTION	TOTAL: HOURS	(HOURS) %	(%)	OPERATIONAL CODE -- DESCRIPTION	TOTAL: HOURS	(HOURS) %	(%)
XX XXXXXXXXXX	XX.X	XX		XX XXXXXXXXXXX	XX.X	X	
XX XXXXXXXXXX	XX.X	XX		XX XXXXXXXXXXX	XX.X	X	
TOTAL OPERATIONAL DELAYS:		(HOURS)	(%)				

TOTAL SCHEDULED DELAYS: TOTAL UNSCHEDULED DELAYS:

HOURS: XX.X % HOURS: XX.X %

FIG. 12 Shovel - BEPAL II, Availability Summary Report (5).

TABLE II

MONITORING DEVICES FOR SHOVELS

Description	Nature of the Manufacturers	Locations Currently Operating	Features	Availability	Remarks
Dige Model 5145	Mining Electronic Equipment, U.S.A. Plantview Ponit Suite 100 10509 Timberwood Circle, Louisville, Kentucky, 40223, USA	Several operations in U.S.A.	Monitors and records machine operating data. Provides shift report on the performance of the machine.	Production is suspended	Proven
Model 173 Shovel Monitor	Interactive Sciences P.O. Box 1896 Sanford, Florida, 32772, U.S.A.	Twenty-five shovels in U.S.A. One on P & H shovel at Fording River Mine, B.C., Canada	Acquire, record and process machine operating data. Provides printed log, shift report and records all activity on a magnetic tape for processing.	Readily available.	It is planned to install this system at Westar's Coal Mine, B.C., Canada
BEPAL II	Bucyrus Erie P.O. Box 56 South Milwaukee WI., 53172, U.S.A.	Canada - 5 + 3 under installation U.S.A. - 3 N. Mexico - 1 Australia - 1 Papua N. Guinea - 1	Monitors and records production and performance data. Provides daily management report machine availability and productivity/ utilization reports.	Readily available.	Proven

BLASTHOLE DRILL:

1) Model 245 Monitor:

It is designed and manufactured by Interactive Sciences Inc. and is in use at several surface mines in the U.S.A. Designed with a microprocessor it acquires, records and processes machine data providing the operator with a display of drill bit depth and penetration rate, as well as other machine functions such as propel time, idle time, total feet drilled during the shift, etc. The onboard plotter prints a StrataGraph of the penetration rate and other parameters for each hole drilled. The system provides a printed log and shift report, and records all activity on magnetic tape for further analysis by the processing system (model 223).

2) Holepro:

It is a microprocessor based performance and production analyzer designed, manufactured and marketed by Bucyrus-Erie's Mining Systems Division for rotary blast hole drills. The primary function of HolePro is to monitor and record changes in material hardness throughout the depth of each hole drilled. The performance data is displayed to the operator via a customized rugged keypad/display. Performance data displayed includes drilling rate, head position, bit position and depth (Fig.13). The options for HolePro systems are:

- On-Board Printer
- Mass Data Storage System
- Data Communications System
- Repeater Station
- Formatting Software

3) GLI's Drilling Efficiency Indicator (DEI):

Manufactured by GLI corporation, Woodenville, Washington this system performs four major functions, the data from which can be used to improve the efficiency of the drilling and blasting operations. First, DEI provides a continuous readout of penetration rates. Differences in penetration rates allows the operator to identify harder and softer rock formations. Second, the system indicates the depth of the hole being drilled. This information, along with changes in penetration rates, allows accurate logging of coal

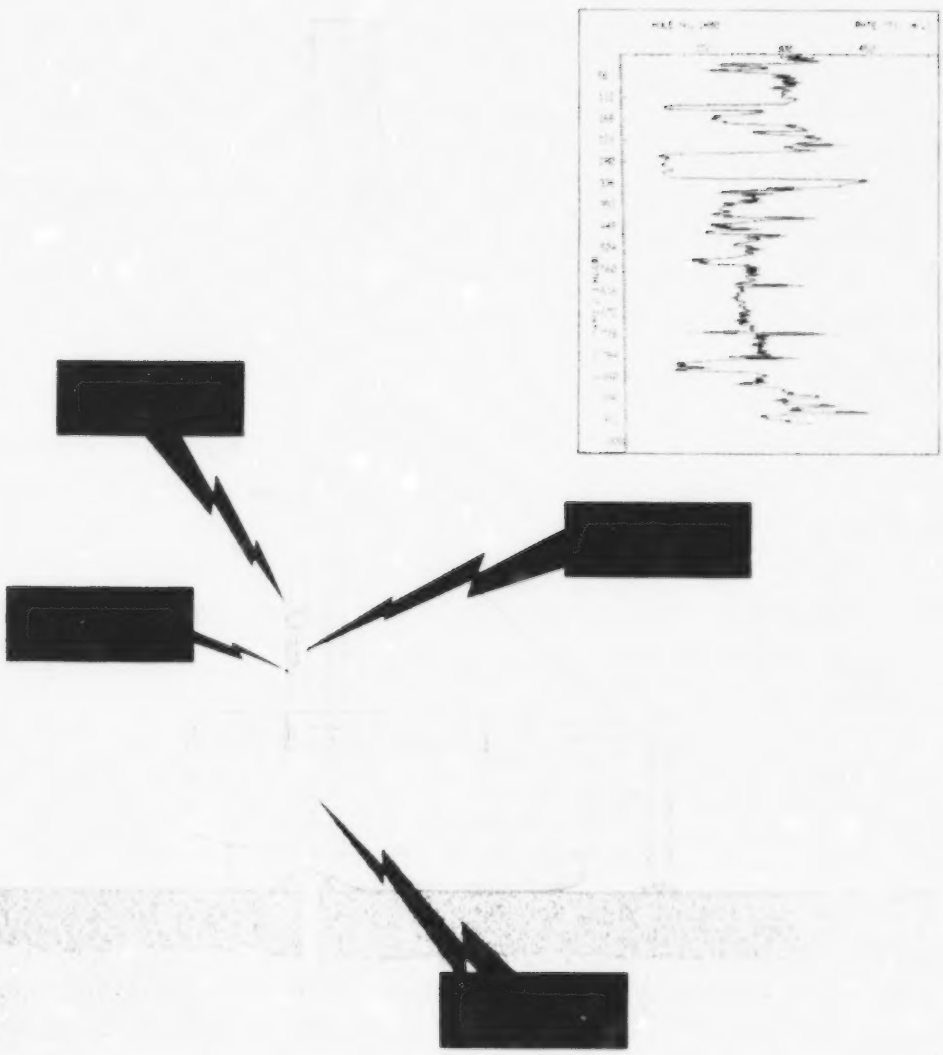


FIG. 13 Holepro drill monitor (5).

seams. It also allows even drilling of holes, which results in a smoother pit floor. Third, DEI records distance of the bit from the hole bottom when rods are changed or holes are cleaned. The operator can then return the bit to the drilling position without striking the bottom of the hole and possibly damaging the bit. Fourth, it keeps a record of total footage drilled (Fig.14).

The DEI system has received world-wide acceptance and is in use in over 100 locations in Australia, U.S.A, and Canada..

The DEI system is expandable. A new module has been designed called "Stratalogger" which can be used in conjunction with the DEI system. This provides a hard copy record of drilling data. At present this module is in use in Australia and U.S.A only. Table III shows a summary of different drill monitoring devices.

FRONT END LOADERS:

1) DIGS Model 5155:

It monitors engine, drive train, hydraulic and lubrication systems to provide immediate warnings of impending system failures before they occur. It consists of an operator's display, control console coupled to a signal conditioner and sensors, all microprocessor controlled. The functions and information provided by this device are similar to the model used for shovels.

BACKHOES:

1) DIGS Model 3232:

This is adaptable to small draglines, hydraulic excavators, bucket wheel excavators, and a host of other mobile equipment. The basic principle and components for data gathering and processing are similar to the models described earlier.

FIG. 14 GLI's DEI System (7).

TABLE III

MONITORING DEVICES FOR DRILLS

Description	Nature of the Manufacturers	Locations Currently Operating	Features	Availability	Remarks
Model 245 Monitor	Interactive Science P.O. Box 1896 Sanford, Florida, 32772, U.S.A.	U.S.A.	Acquires, records and processes data i.e. penetration rate, bit depth, footage drilled etc. Provide stratagraph, shift report printed log. Records all activity on magnetic tape.	Commercially available.	Proven
Holepro	Bucyrus Erie P.O. Box 56 South Milwaukee, WI. 53172, U.S.A.	U.S.A.	Monitors and records data, i.e. penetration rate, depth, bit depth for hole bottom.	Commercially Available	Recently introduced
Drill Efficiency Indicator (DEI)	GLI Corporation P.O. Box 245 Woodinville, WA 98072, U.S.A.	Over 100 locations worldwide. In Canada: Quintette - 2 nos Bullmoose - 3 nos Greenhills - 1 on order Gregg River - 1 on order Adams Mine, Ont. - 1 on order IOC, Que. - 1 on order	Monitors performance i.e. penetration rate Hole depth Distance of bit from hole bottom and record of footage drilled. Additional feature is "Stratalogger" currently in operation in U.S.A. and Australia	Commercially Available	Proven

OFF-HIGHWAY TRUCKS:

1) GLI's Vehicle Management System (VMS):

This system is currently operating at Centralia Mine in Washington State; the Reserve Mine, Babbitt, Minnesota, and at Island Copper, British Columbia. It has been fitted to Euclid, Dart and Unit Rig trucks. It consists of sensors, microprocessor based control electronics and a display unit (Fig.15). The sensors are designed to withstand harsh conditions found in off-highway applications. These are connected to the microprocessor through flexible tubing. The microprocessor and the control electronics which monitor the sensor inputs are all mounted in a sealed metal box. Information is presented either on the dash mounted display or retained in memory to be retrieved later. It can also be relayed to a central control room by radio so that management and maintenance personnel can continuously monitor the status of the entire fleet. It continuously monitors engine drive, train and other vital functions; including pressures, oil levels, temperatures, electrical outputs, speed and engine rpm.

2) On Board Truck Weighing Systems:

Several studies have been carried out to determine the safety hazards and the economic implications of overloading mine-haulage trucks (10). These studies show that:

- Ten to twenty five percent overloading is typical.
- Higher haulage, tire and maintenance costs occur due to overloading. A twenty percent overload was estimated to increase operating costs by seven percent per tonne.
- Ten to fifteen percent of haulage truck injuries and fatalities are attributable to overload conditions, at a cost of over one million dollars per year.

In order to overcome the problem of truck overloading the U.S Bureau of Mines initiated a field test program. Since then independent developers have been involved and the haulage truck overload detection devices are now available off the shelf and must be considered as an option when a truck purchase is made. By providing a precise measurment an overload detection system will not only indicate vehicle overloading but will also show under utilization of the truck.

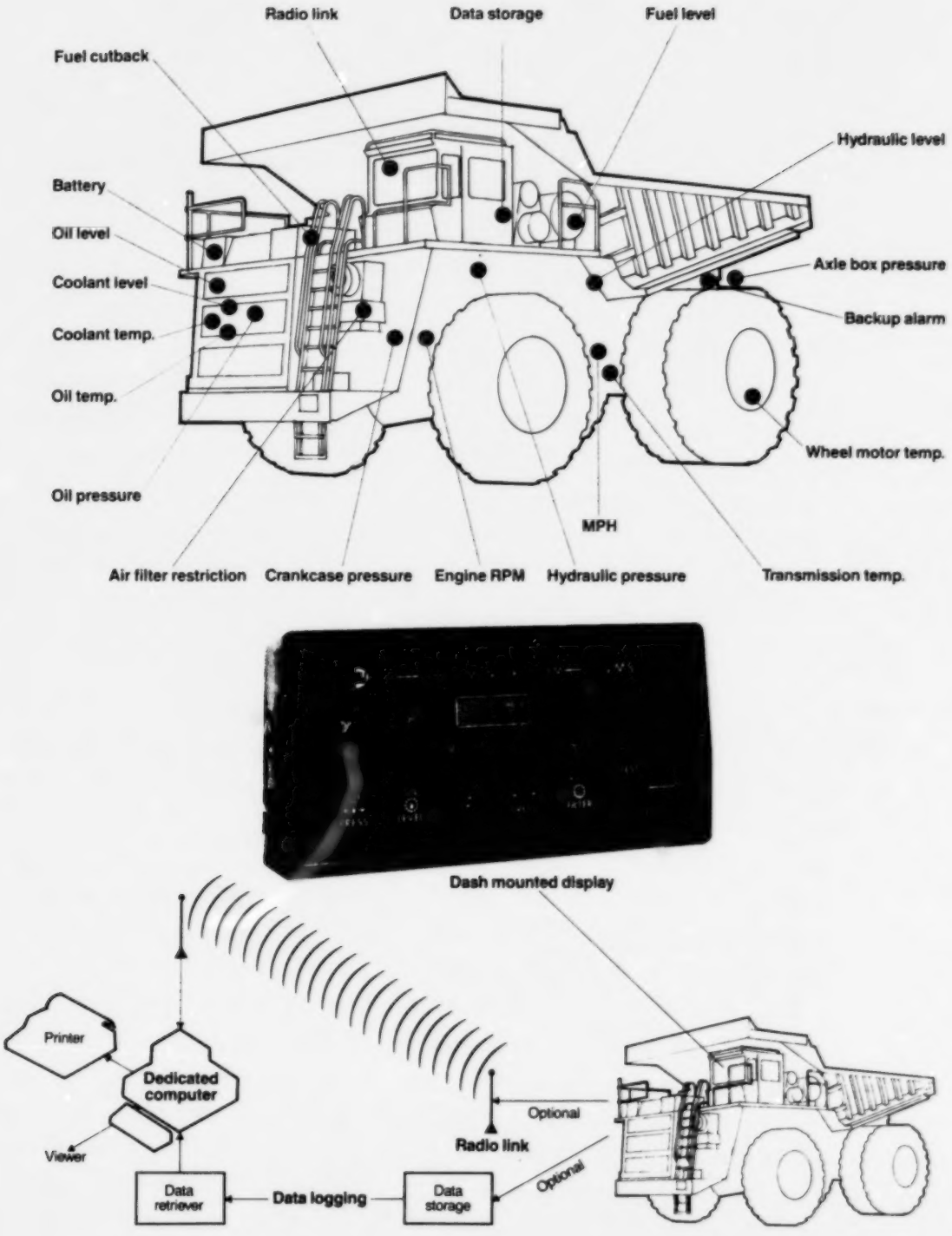


FIG. 15 Vehicle Management System (7).

One system tested by the U.S Bureau of Mines (USBM) was the "Load Analyzer" manufactured by Pactronics Corporation in California. This system consists of a meter-type analog readout for the cab console and three linear variable differential transformers attached to the main frame. Two sensors are attached between the front members of the engine subframe and the top of the left and right trailing arms (one sensor per arm). The third sensor is attached to the rear centre line of the truck, between the main frame cross member and the A-frame. The readout unit on the cab console indicates by colour coding whether each sensor loading is under (green), at (yellow) or over (red) the pre-set rated load. The three sensor configuration with independent readouts also detects uneven distribution of the load.

Another system tested by the USBM the "Load Indicator" manufactured by ASEA Incorporated of New York consists of four magnetoelastic force transducers, a digital display unit for the cab console and external loading lights visible to loading shovel operators. Using a special spot-brazing technique, two sensors are attached to the left and right bottom of the main frame under the front pads and two more sensors are attached near the left and right hinge pins. The digital readout of the four sensor configuration indicates front, rear, total net or gross weight and shows uneven distribution of the load.

Both of these, like any overload detection systems must be calibrated upon installation using an accurate weighing apparatus. Once calibrated periodic checks should be made at least twice a year to assure accuracy.

3) OBDAS SYSTEM:

Another system is available under the trade name of OBDAS from Phillippi-Hagenbuch Inc., Peoria, Illinois. A typical truck equipment performance system (Fig.16) consists of:

- Load/weighing sensors
- Transmission/vehicle direction monitor F-N-R
- Dump switch
- Microprocessor with built in battery back-up clock
- Vehicle control number status/keypad
- Display
- Printer

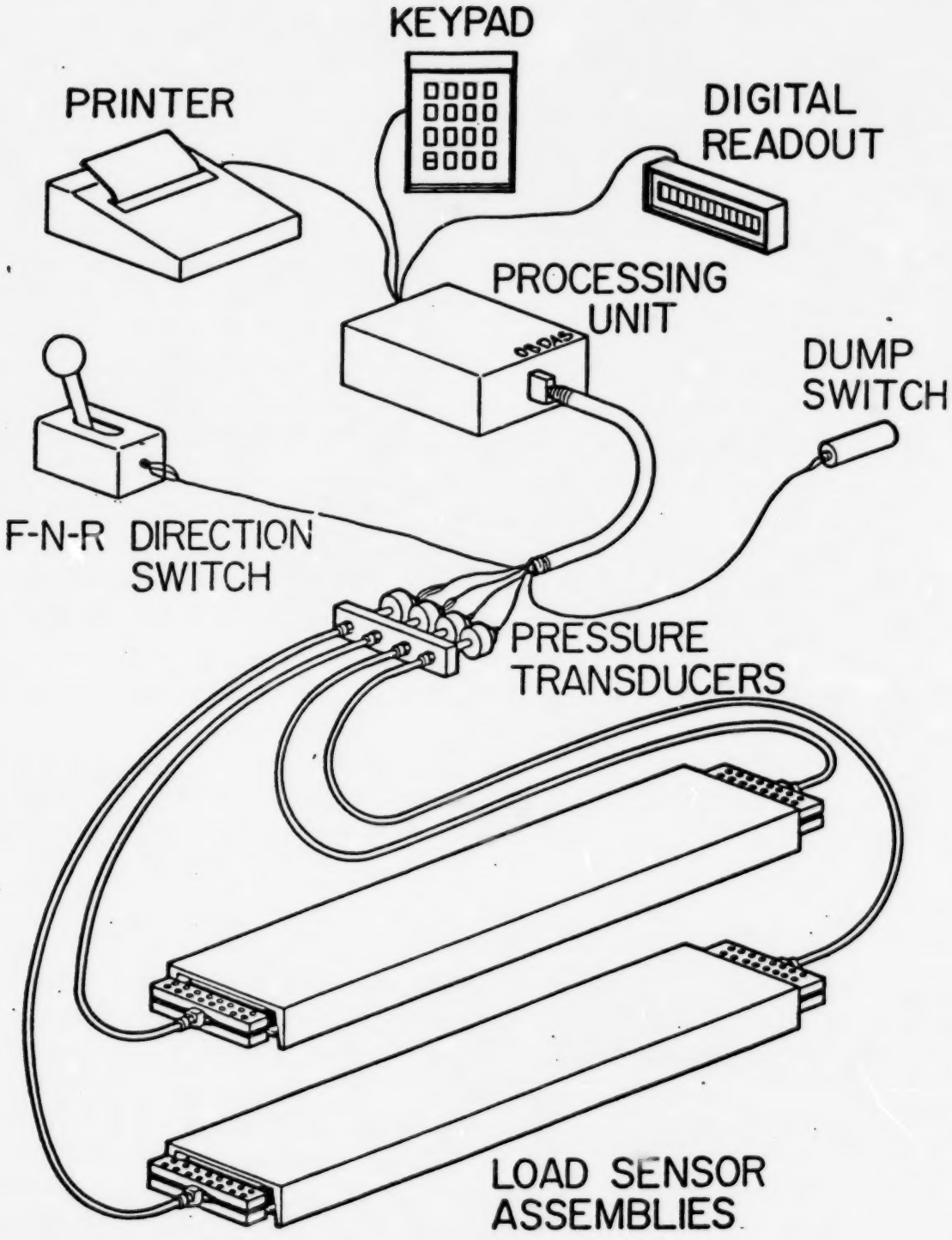


FIG. 16 OBDAS System (3).

This system provides: haul cycle segment breakout, truck status, being loaded, loaded, unloaded, in service/out of service (Fig.17). Optional: vehicle location, vehicle loading equipment status in service/out of service, information as to distance travelled in each haul cycle segment.

Several advanced options are available which provide information on the following:

- Loading equipment analysis
- Haul back monitor
- Haul road condition monitor
- Weight distribution
- Distance measurement
- Fuel consumption
- Grade monitoring and
- Axle load analysis

Work is in progress to integrate this system with a complete Mine Information System which will include vehicle location and truck dispatch.

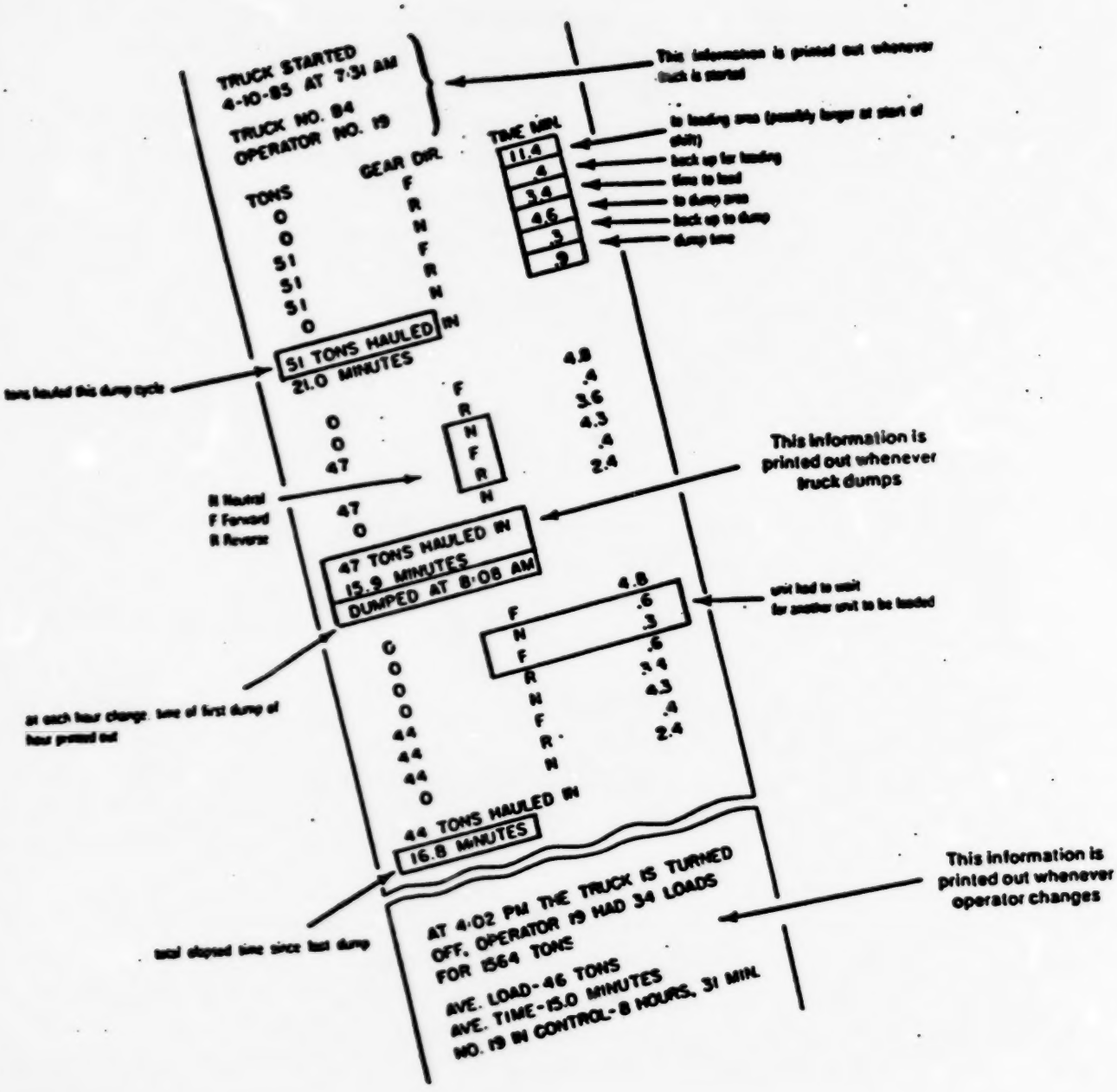
Two trucks have been equipped with this system at Gregg River Mine and are being evaluated as part of a cooperative demonstration project between Gregg River and CANMET.

4) TIACS System:

This has been developed by TRW Transportation, Electrical and Electronics operations Division of Salon, Ohio. It has following characteristics (11):

- time sharing of certain system components
- multiple uses and service conditions by individual operators
- easy modification and addition to the existing system
- recording and monitoring capability for improved asset management and reduction of diagnostic and maintenance costs
- programmed overhauling schedules
  introduction of new technologies when current systems are obsolete without a major disruption to the basic vehicle system
- system flexibility for options

The basic element of this system called Serial Communications Link (SCL) allow various electronic systems and sub-systems to communicate, exchange data and cooperate while certain systems can also act independently



NOTE: Minor variations in tonnage on same load may occur due to dynamics on load of starting and stopping.

FIG. 17 Typical OBDAS Output (3).

TABLE IV

MONITORING DEVICES FOR TRUCKS

Description	Nature of the Manufacturers	Locations Currently Operating	Features	Availability	Remarks
Vehicle Management System (VMS)	GLI Corporation P.O. Box 245 Woodenville, WA., 98072, U.S.A.	Washington, U.S.A. Minnesota, U.S.A. British Columbia, Canada	Monitors the engine, drive, train, pressure levels, temperature electrical outputs and motion (MPH/RPM)	Commercially Available	Proven
On-Board Data Acquisition System (OBDAS)	Philippi-Hagenbuck Inc., 7424 W. Plank Road Peoria, Illinois U.S.A.	Gregg River Mine, Canada Under trial.	Monitors and records operating data as well as equipment performance data.	Commercially Available	Under test in Canada
TIACS System	TRW Transportation Electrical & Electronics Division Salon, Ohio, U.S.A.	U.S.A.	Monitors and records truck performance data	Commercially Available	Proven

of a master control unit if required.

The different sub-systems provide the following:

- driver comfort
- driver and vehicle safety
- performance monitoring and controls
- information displays and
- vehicle maintenance and diagnostics.

Several other systems are also available which have been designed, manufactured and tested namely ETEC system, TSS system etc. The principal objective of most of these systems are to provide equipment performance data and control machine at limiting conditions.

DISCUSSION:

This report briefly mentions the product of a few manufacturers summarized in tables I to IV. This list is far from complete. It is however considered that the Canadian surface mining industry will be interested in this overview. It is considered that monitoring the performance of mining equipment is cost effective.

Microprocessor technology has already proven its worth in enhancing the overall economics of mine operations worldwide. A variety of monitoring devices are currently available. Some of these are already in use in Canada and others are being tested in Canadian mines. In addition to monitoring discrete pieces of equipment there is merit in linking the individual systems to a central computerized management system. With this addition planning, machine utilization, new equipment selection, quality blending, training and staffing all become more efficient. We understand that several Canadian mining operations at present are actively looking into introducing such equipment and trust that this overview is both timely and relevant to their needs.

It is expected that in the near future, most mining operations (drilling, blasting, haulage, water handling, coal preparation, maintenance and repair) will be linked to a central mine data management centre resulting in enhanced productivity and reduced operating costs.

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